MARTEN HABITAT SUITABILITY RESEARCH PROJECT

WORKING PLAN

Ministry of Environment
Victoria, B.C.

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Wildlife Branch
Ministry of Environment
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SUMMARY

In a 1987/88 Habitat Conservation Fund proposal entitled "Habitat Suitability Evaluation for Marten (*Martes americana*)", Steventon (1987) outlined the rationale for developing a predictive model of marten habitat suitability. The proposed project was to provide the basis for consideration of marten in forest management within the Sub-Boreal Spruce zone (Pojar *et al.* 1984). This working plan describes the process of developing a habitat suitability index model for marten in the Sub-Boreal Spruce zone, details the research necessary to develop the model and identifies a schedule and budget for the project.

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1.0 INTRODUCTION

1.1 Purpose

This report outlines a working plan for an intensive research program aimed at developing a habitat suitability index (HSI) model for marten (*Martes americana*) in the Sub-Boreal Spruce (SBS) biogeoclimatic zone of British Columbia. The report describes the rationale for such a program, identifies the habitat-related research needs for marten, and the research objectives for this project. Research hypotheses, methods of data collection, model development, verification, and application are described. A proposed project schedule and budget are presented. This document is intended to act as a guide for carrying out this research program.

1.2 Rationale

Marten are found throughout the forested regions of much of Canada, Alaska, and portions of the western and northeastern United States (Strickland *et al.* 1982). Their range has shrunk in the south due to loss of suitable habitat (Strickland *et al.* 1982; Raphael 1986). The northern limit of their range coincides closely with the treeline (Strickland *et al.* 1982).

In British Columbia marten are, in economic terms, the most important furbearer harvested. From 1986/87 to 1988/89, 32 000 - 39 000 marten were harvested annually, worth $2.9 to $3.7 million (59-81% of the total value of all B.C. furs).

The sub-boreal forests of British Columbia are important timber-producing regions. Extensive clearcut logging occurs annually throughout the Sub-Boreal Spruce (SBS) biogeoclimatic zone. The *Ministry of Forests Act* (1978) and the *Forest Act* (1978) state that provincial forests are to be managed and used for a variety of purposes, including wildlife habitat (Harcombe 1984). The rate of cut and associated silvicultural activities in the SBS zone could have potentially serious implications for some wildlife, particularly old forest-associated species such as marten. Problems arise largely from a lack of understanding of habitat needs of marten in this zone, and a lack of tools for managers to assess, prevent, and alleviate serious impacts to marten habitat and their consequent inability to enhance the same. Thus there is a risk of being unable to meet the objectives for the conservation and management of marten.

The sensitivity of marten to habitat change through logging and silvicultural practices has been reported consistently in the literature (British Columbia - Kelly 1982; Maine - Soutiere 1979, Steventon and Major 1982; Minnesota - Mech and Rogers 1977; Newfoundland - Snyder and Bissonette 1987; Ontario - Thomson 1986; Wyoming - Clark and Campbell 1977, Campbell 1979). The age at which regenerating clearcuts are used by marten varies among studies. In Wyoming, marten did not use clearcuts for at least a year after cutting (Clark and Campbell 1977). In Maine, marten rarely used clearcuts <15 years old but were found in partially harvested stands (Soutiere 1979). Snyder and Bissonette (1987) reported that 23-year-old regenerating stands were insufficient to support marten in Newfoundland whereas in Ontario, Thompson (1986) found that marten used clearcuts in winter after only 10 years. Thus rapid clearcutting could seriously degrade habitat suitability for marten.

Little information is available on the effects of silvicultural practices, but they will undoubtedly play an important role in marten use of regenerating clearcuts and second-growth forests. Stordeur (1986) discussed the following possible ramifications of current silvicultural practices in British Columbia. As marten do not typically use recent clearcuts in winter, scarification will not directly affect marten. Exposure of the soil may alter the moisture regime and affect the composition of

regenerating understory, which in turn may influence marten prey populations. Fertilization increases the understory vegetation, possibly augmenting prey populations. "Clean" site preparations, the removal of logging debris and the regenerating understory, will affect marten negatively by removing cover, and hunting and den sites. Pre-commercial thinning in plantations is likely to be beneficial because opening the canopy promotes understory growth and prey abundance, and woody downfall is created. The degree of spacing, however, will be important in determining the value of canopy cover for marten. Commercial thinning, essentially logging in established stands, is unlikely to affect marten adversely. The effects of herbicides on marten habitat use are unknown but may be adverse if numbers of prey species decline in herbicide-treated sites.

Fires alter cover and the edaphic nature of a site. Wildfires may act beneficially by creating a mosaic of habitat types that support a diversity of prey. Results probably depend on the type of ecosystem, and the size and severity of the fire. In Alaska, Magoun and Vernam (1986) demonstrated that marten are adapted to wildfire-driven ecosystems. Burns were used by marten but cover provided by wind-thrown trees was a critical component of their habitat. Prescribed fire, as a site preparation, has the potential to reduce the value of a clearcut for marten by eliminating cover, snags, logs and other features important in marten habitat use.

Marten generally prefer coniferous or mixed-wood forests and tend to be associated with old forest conditions (Strickland *et al.* 1982; Strickland and Douglas 1987). In the United States, marten have been used as an old-growth indicator species (Wischnofske 1978 in Harcombe 1984; Irwin and Cole 1987) due to their restricted habitat requirements. Marten will, however, tolerate younger seral conditions providing specific habitat needs are met. There is evidence that marten inhabiting these younger seral conditions have larger home ranges and lower population densities (Soutiere 1979).

Several studies have indicated that provision or maintenance of habitat for marten need not always be incompatible with logging practices (Koehler *et al.* 1975; Soutiere 1979; Steventon and Major 1982; Snyder 1984). However, foresters and wildlife habitat managers often lack the information necessary to assess the suitability of habitat for wildlife or to predict impacts of timber harvesting (Harcombe 1984). A habitat suitability index (HSI) model has been selected as the most suitable tool for managers to address this problem. This project will provide the biological understanding required to develop a reliable product, the HSI model, and transfer the product and knowledge to managers.

1.3 Research Needs

The previous section outlined the needs of resource managers for better tools for managing habitat. Harcombe (1984) identified a number of problems wildlife managers and foresters face in managing habitat. Most importantly, information regarding the relationships of many wildlife species with their habitat is widely scattered and poorly understood. In addition, this information is not readily available to land managers in a system that can be used to predict the impact of their management activities on wildlife. This is especially true for furbearers, which tend to be secretive and use habitats in ways not readily apparent. The development of the tools needed for managing habitat requires the fulfilment of a number of research needs. The research needs for marten (and other wildlife) have been described in more detail by others. Stordeur (1986) made a number of recommendations for furbearer research in B.C., many of these directed specifically at marten. They included the determination of resting and den site characteristics, the determination of food habits and hunting site characteristics, and the determination of how impacts of forestry practices on marten can be lessened. A recent problem analysis on furbearer research needs within the province (Blood 1988) identified some high priority issues related to the forest industry and furbearer habitat. These issues

include a lack of integration of furbearer and forest management, the unknown impacts of various silvicultural practices on habitat and the potential impacts of herbicides on prey bases. The two top priority research topics identified involve marten: habitat selection and use by marten (and lynx) in logged and unlogged areas, and population parameters of trapped and untrapped marten (and lynx) populations.

1.4 Research Objectives

Based on the above information, and recognizing the need for a practical limit to research projects, the following goals and objectives were developed for this research project. The main goal of this research program was to determine the extent to which marten may be affected by logging and silvicultural practices and to explain why these effects occur.

The transfer of information from research such as this to foresters and wildlife habitat managers is a critical part of applied research. The use of handbooks and habitat suitability models is an effective means of facilitating this transfer (Harcombe 1984). Most of the research needs identified above can be addressed through the development of an HSI model for marten. Wildlife managers throughout the province identified the development of HSI models for furbearers as a high research priority (Blood 1988). The important feature of such models is the ability to predict the habitat attributes necessary to achieve a desired habitat capability in a managed forest. In this way, needs of marten and associated species can be addressed in conjunction with forest practices.

To meet this goal the following research objectives have been identified:

1. To provide the biological understanding needed to develop and substantiate an HSI model for marten in SBS forests.
   - 1.1 To document winter habitat selection by resident marten.
   - 1.2 To describe sites used for resting and maternal dens.
   - 1.3 To describe winter habitats used by marten in terms of habitat types and habitat variables.
   - 1.4 To document marten winter diet.
   - 1.5 To estimate prey base and relate it to diet and habitat variables.
   - 1.6 To describe and quantify the relationships between habitat variables and their provision of marten life requisites.

2. To develop, verify, and document an HSI to help managers integrate forest management with marten habitat needs.
   - 2.1 To incorporate the relationships between habitat variables and life requisites into a model that allows the assessment of an area of land for its suitability as marten winter habitat.
   - 2.2 To evaluate the utility and reliability of this model as a management tool by testing it in a variety of habitat conditions in the SBS zone.
   - 2.3 To use the results of this evaluation to refine the model.
   - 2.4 To develop the Habitat Capability Model that ties the HSI model to population attributes.
   - 2.5 To document all aspects of the model and its use.

3. To transfer the tool and understanding to managers.
   - 3.1 To develop a training program for resource managers.
   - 3.2 To conduct training sessions across the SBS zone.
   - 3.3 To evaluate the success of the tool in improving the integration of marten habitat needs into forestry planning and management.

2.0 HSI MODEL DEVELOPMENT

There are a variety of ways in which resource managers can better consider marten habitat needs in forest management. The most suitable approach for interior B.C. appears to be the use of HSI models. These models are the basis of the habitat evaluation procedures developed by the United States Fish and Wildlife Service (USFWS) to assess the impacts of proposed water and land resource developments on fish and wildlife habitat (Schamberger and Farmer 1978; U.S.Fish and Wildlife Service [USFWS] 1980; Cooperider 1986). HSI models are designed to predict the value of habitat units to wildlife populations based on a number of habitat parameters (Cooperider 1986). The model is a series of mathematical equations that relate habitat variables to habitat suitability. Habitat suitability is a relative index scaled from 0 to 1 and can be related to wildlife populations through the use of habitat capability models (HCM) (Cooperider 1986). Population attributes of HCM's may range from presence/absence information to detailed population dynamics. HSI model development involves the following steps (USFWS 1980; USFWS 1981; Cooperider 1986):

1. set model objectives;
2. identify model variables;
3. structure the model;
4. document the model;
5. verify the model.

2.1 Existing Models

Five HSI models for marten have already been developed (Table 1).

The life requisites and habitat variables considered in each of these models are outlined in Table 2. Only Barrett and Spencer (1982) document attempts to verify an HSI model for marten, with mixed results. None of these models are developed for ecosystems that resemble the SBS zone. Except for one, they are derived from literature either not directed at producing an HSI model or not directly applicable to the area of application of the model. As a result none of these models are appropriate for application in the SBS zone. They can, however, be used as a platform upon which to develop such a model.

2.2 Model Components

2.2.1 Model objectives.— An ideal HSI model has a direct linear relationship between the index and carrying capacity (USFWS 1980). In reality this is rarely attained, thus criteria for acceptable model outputs must be defined. These identify the level of reliability the model should attain. There are three steps to setting model objectives:

1. define geographic area of model applicability;
2. define seasonal applicability of model;
3. define ideal and acceptable model outputs.

Geographic Area

The model will be applicable to the Sub-Boreal Spruce (SBS) biogeoclimatic zone of British Columbia (Pojar *et al.* 1984). The SBS zone occurs in the central and northern interior of B.C. (Fig. 1) and includes a large part of the province's marten population and marten habitat.

Season

The model will define winter habitat suitability for marten. Winter is a critical season for marten due to reduced foraging opportunities, restricted mobility and increased thermoregulatory costs (Raine 1983; Hargis and McCullough 1984; Gordon 1986; Suring 1987; Buskirk *et al.* 1988).

Minimum Area of Application

The model will be applicable to areas as large or larger than the average home range size of adult female marten. This will be determined from radio-collared individuals in the intensive study area. It may be applied to smaller areas to identify limiting habitat factors in these areas.

Table 1. Existing marten habitat suitability models.

Author/date	Area of application
Shimamoto and Airola 1981	Northern California
Allen 1982	U.S. Coniferous Forests
Barrett and Spencer 1982	California Sierra Nevada
Patton and Escano 1983	Central Rocky Mountains, Columbia Highlands and Rocky Mountain Forest Provinces
Suring 1987	Southeast Alaska

Table 2. Habitat variables used to meet life requisites in existing marten HSI models.

Source	Life requisite	Habitat variables
Airola and Shimamoto 1981	All	Vegetation type Vegetation pattern Distance from water Volume dead and down woody material Meadow productivity Elevation Human disturbance
Allen 1982	Winter cover	Successional stage Volume dead and down woody material Canopy cover Percent of fir or spruce in canopy
Barrett and Spencer 1982	Food	Canopy cover Soil moisture Successional stage Percent of fir in canopy
	Cover	Canopy cover
	Dens	Canopy cover Successional stage Percent fir in canopy
Patton and Escano 1983	Food	Soil moisture Canopy cover Average tree size Volume dead and down woody material
	Cover	Canopy cover
	Dens	Volume dead and down woody material Percent fir or spruce in canopy
Suring 1987	Food/cover	Canopy cover Elevation Snag index Volume dead and down woody material Road density Stand age

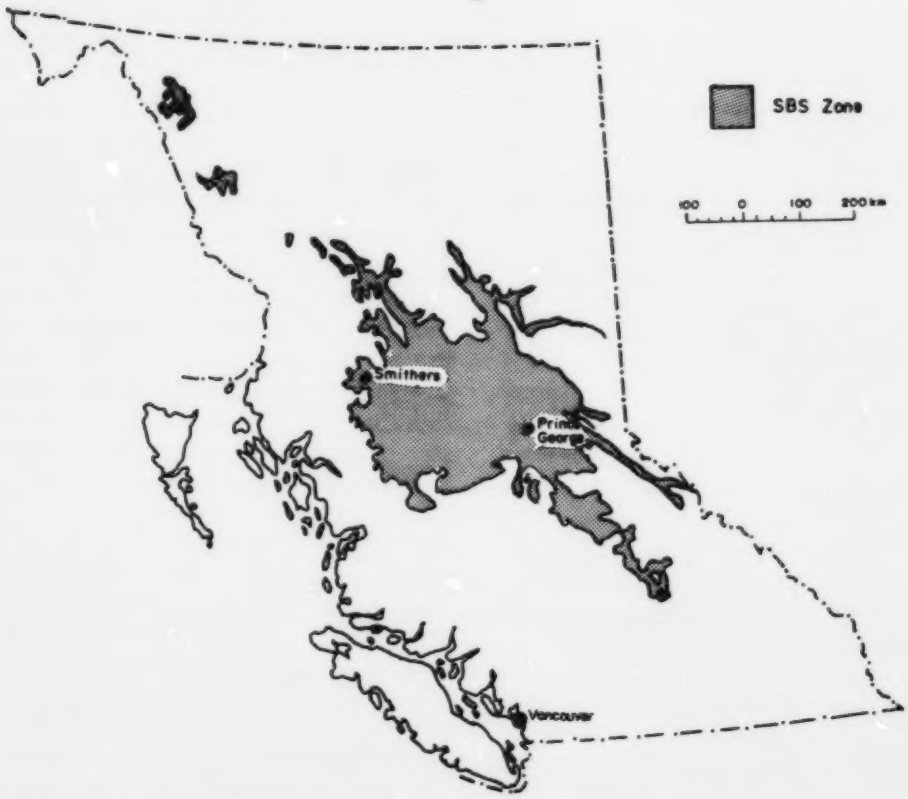

Figure 1. Distribution of Sub-Boreal Spruce biogeoclimatic zone in B.C.

Sex

The model will define habitat suitability for both male and female marten. Evidence suggests that female marten may have more specific denning habitat requirements while raising young (Wynne 1981). Natal dens will be investigated and, if differences exist between these and resting den sites, they will be incorporated into the model.

Model Outputs

Identifying acceptable model outputs involves defining tolerable margins of error or variability for the HSI. The marten HSI model outputs will be considered acceptable if:

1. suitability ratings for marten habitat are "reasonable", considering knowledge of the ecology of the species (USFWS 1981);

2. suitability ratings correspond to actual levels of marten habitat use as indexed by track counts or other indices within the intensive study area;

3. suitability ratings correspond to actual levels of marten habitat use as indexed by track counts or other indices within selected verification study areas.

Suitability ratings will be derived from information gathered in the process of literature review and monitoring habitat use. Track census indices will be used to test and refine the rating system. The degree of accuracy (and utility) of the model and a measure of variance can be obtained by comparing observed to predicted values. This will also lead to model refinement.

2.2.2 Model Variables.— Model variables are the components that form the basis of the model equations. They consist of the species' life requisites and the habitat variables that are used to meet those life requisites.

Marten habitat use has been examined by several researchers in various parts of North America. Reviews are in Strickland *et al.* (1982), Allen (1982), Stordeur (1986), Irwin and Cole (1987), Suring (1987) and Strickland and Douglas (1987). Identifiable life requisites for marten include water, food, foraging sites, resting and maternal den sites, security cover, and a suitable interspersion of habitat types providing these requisites.

Habitat variables are the building blocks of HSI models. Each life requisite is represented by one or more habitat variables. A suitability index will be obtained for each life requisite based on the combined measures of its associated habitat variables. Variables are chosen on the premise that "if modified they would be expected to affect the capability of the habitat to support the evaluation species" (USFWS 1981), thus the habitat variables should meet three criteria:

1. they are related to the capability of the habitat to support the species;

2. there is a basic understanding of the relationship of the variables to the species' habitat needs;

3. the variables are practical to measure within the constraints of model application.

The life requisites and habitat variables proposed to be used in this model are outlined in Table 3. The reasoning for the selection of habitat variables for each life requisite follows.

Water

The requirement for water is unimportant in an HSI model defining winter habitat due to the availability of snow. It will not be part of this model.

Food

Small mammals such as voles (*Clethrionomys* spp. and *Microtus* spp.) have commonly been identified as important winter foods for marten (Lensink *et al.* 1955; Weckwerth and Hawley 1962; Francis and Stephenson 1972; Buskirk and MacDonald 1984; Hargis and McCullough 1984; Gordon 1986). Thompson (1986) suggested that larger prey such as hares and grouse may be more important energetically, especially when typical smaller prey species are less available. Site productivity and availability of security and thermal cover for small mammals may be important factors in determining their abundance.

Table 3. Habitat variables providing life requisites for the proposed marten HSI model.

Life requisite	Habitat variables
Food	Soil moisture Volume dead and down material Low shrub cover
Foraging Sites	Volume dead and down material Snag density Coniferous canopy cover
Resting Den Sites	Volume dead and down material Snag density Tree size
Maternal Den Sites	Snag density Volume hard dead and down material
Security	Coniferous canopy cover
Interspersion	HSI mean and variance measures

The moisture regime of a habitat type may be representative of site productivity. Small mammal abundance has been correlated with habitat moisture regime (Corn *et al.* 1988). Small mammals may not be as abundant in wetter sites (subhydric and hydric), however, as surface and sub-surface water may reduce subterranean habitat availability. Small mammal abundance has also been correlated with the cover of low shrub and herbaceous vegetation. These may be related to site productivity but low shrubs flattened by snow may also provide subnivean habitat. Initial assessment of habitat in the Sub-Boreal Spruce Zone suggests that small mammal abundance may be highest in those habitats that have between 30% and 100% low shrub cover and at least 100 m^3/ha of dead and down woody material.

Foraging Sites

Hunting sites for small prey are subnivean, therefore access to these sites for marten is important. Access to subnivean hunting sites is provided by downed and leaning logs, decayed stumps and trees of large diameter (Clark and Campbell 1977; Hargis 1982; Steventon and Major 1982). In Alaska, Suring (1987) suggests that at some elevations excessive snow depth may preclude marten activity.

Studies indicate that marten prefer forests with 30% to 80% coniferous canopy cover and generally avoid areas with little or no canopy cover (Buskirk 1984; Koehler *et al.* 1975; Spencer *et al.* 1983). Spencer *et al.* (1983) reported that marten showed preferences for sites with at least 125-200 logs/ha and 3-6 m^2/ha basal area of snags. Preliminary assessment of the subalpine fir subzone of the Sub-Boreal Spruce Zone indicates that those sites with at least 100 m^3/ha of dead and down logs at least 20 cm in diameter, 5 m^2/ha basal area of snags at least 20 cm in diameter, and at least 30% coniferous canopy cover provide the best foraging habitat.

Resting Den Sites

Marten, as most small mustelids, have strict thermoregulatory requirements due to short pelage and a high body surface to volume ratio (Brown and Lasiewski 1972). Consequently, marten require resting sites that reduce thermoregulatory costs. Bergerud (1969) suggested that den site availability may be limiting to marten populations. These sites are often associated with large woody debris, decayed logs, squirrel middens, burrows, stumps, and logs (Buskirk 1984; Buskirk *et al.* 1989). In general, they are located under snow cover (Spencer 1987). In wet conditions, such as those in late winter/early spring, marten may use resting sites above ground. These may include snags, slash piles and logging debris (Clark and Campbell 1977; Steventon and Major 1982), and man-made structures (Spencer 1987).

Resting den site characteristics are, to some extent, similar to those of foraging sites. Large live trees may also be important by providing resting den sites in well developed, large root masses. Preliminary results indicate that these trees should be at least 40 cm dbh.

Maternal Den Sites

There is little documentation of maternal den site requirements for marten. Evidence from the literature suggests that females select sheltered sites (Bergerud 1969; Wynne 1981). Because kits are born in mid-March to late April, wet weather conditions and residual snow probably greatly influence den site selection. Wynne (1981) suggests that females select natal den sites and move to other sites once kits become mobile and that these sites may be limiting to marten populations. Snags and above ground woody debris may be used as maternal denning sites.

Security Cover

Limited evidence suggests marten may be susceptible to predation by coyotes (*Canis latrans*), lynx (*Felis lynx*), cougar (*Felis concolor*), fisher (*Martes pennanti*), red fox (*Vulpes vulpes*), bald eagles (*Haliaeetus leucocephalus*), golden eagles (*Aquila chrysaetos*), and great-horned owls (*Bubo*

virginianus) (Strickland *et al.* 1982; Strickland and Douglas 1987). Escape from terrestrial predators may be accomplished by climbing trees. Overhead canopy cover may provide protection from aerial predators.

Interspersion

Marten select habitats by optimizing foraging and reproductive benefits against thermal and security costs (Spencer 1981 in Suring 1987). High quality habitat provides all life requisites arranged within a specified area (Buskirk 1983 in Suring 1987). Habitats that fail to provide all life requisites will not be as valuable as those that do. The value to marten of a particular habitat that lacks a life requisite will depend on the distance to the nearest available habitat that contains that requisite. Field evaluation of this attribute is often difficult. However, techniques for the measurement of interspersion from habitat mapping have been developed, verified and tested (Heinen and Cross 1983; Lyon *et al.* 1987).

2.2.3 Model Relationships.— In general, model structure for this HSI will follow that suggested by USFWS (1981). HSI models are hierarchical structures of equations. The lowest level of this hierarchy is the relationship between habitat variables and the provision of a life requisite (Appendix A). These are combined into one equation that derives a suitability index for each life requisite (Eq. 1). The suitability index of a habitat type is derived from the combination of suitability index ratings for each life requisite (Eq. 2). Geometric or arithmetic means used in these equations depend on whether the relationships of the variables used in the equations are compensatory or additive (Eq. 3*a* - arithmetic, 3*b* - geometric) (Barrett and Spencer 1982; Suring 1987). The habitat suitability index of an area that consists of several habitat types equals the sum of the suitability indices of each of the habitat types weighted by the proportion that each type contributes to the total area (Eq. 4).

2.3 Model Verification

The HSI model will be verified in the following ways (USFWS 1981):

1. operating the model with sample data which mimic various habitat conditions and examine how well the model reflects these conditions (sensitivity analyses);

2. review by species authorities;

3. testing the model with field data. This is usually done after the first two steps. Collection of verification data can be conducted simultaneously to the rest of model development. This testing may lead to model revision and refinement of a new model acceptance level (USFWS 1980; Barrett and Spencer 1982).

2.4 Model Application

When developing resource management tools, products should be tailored to the situations in

Eq. 1 $SI_{\text{maternal dens}} = (SI_{\text{snags}} + SI_{\text{dead and down material}})/2$

Eq. 2 $HSI_{\text{habitat type}} = (SI_{\text{food}} + SI_{\text{foraging}} + SI_{\text{maternal dens}} + SI_{\text{security}})/4$

Eq. 3*a* $SI_{\text{maternal dens}} = (SI_{\text{snags}} + SI_{\text{dead and down material}})/2$

Eq. 3*b* $SI_{\text{maternal dens}} = (SI_{\text{snags}} \times SI_{\text{dead and down material}})^{1/2}$

Eq. 4 $HSI_{\text{area}} = (HSI_{\text{habitat a}})/2 + (HSI_{\text{habitat b}})/2$
(where area of habitat a = area of habitat b)

which the tools are intended to be used. The tools must also be delivered to the end users in a form that is easily understood and readily applied.

Resource managers often work within tight time constraints and restricted budgets. This may limit their ability to gather new data for managing habitat. Therefore it is important that the HSI model be tied as closely as possible to currently available data sources. These include forest cover, biogeoclimatic and biophysical mapping and provincial forest inventory statistics. It may be necessary, once the model is developed, to derive readily available surrogates for some of the habitat variables, which will entail examination of possible relationships between model variables and elements of these currently available data sources. Correlations between model variables and elements such as forest cover type, age class, site class and height class will allow the model to be more easily incorporated into the current forest management framework. Failing this, methods of collecting model variable information should be incorporated into the timber inventory process.

The model must function at an appropriate scale. It is proposed that this HSI model be applied at scales of 1:5000 to 1:20 000. This range of scales applies to most site-specific forest planning. A generalized version of the model may be developed to be applied at a scale more appropriate for planning exercises such as TSA analyses.

Adequate training is necessary to deliver the model into the hands of resource managers. Training sessions should be conducted in Ministry of Environment regional offices and Ministry of Forests district offices throughout the SBS zone.

2.5 Model Documentation

The HSI model will be documented in a user's guide. This will consist of sections describing habitat requirements for marten, the justification for the selection of model variables (life requisites and habitat variables), the relationships between model variables, field assessment of habitat variables, the ties between field assessment of habitat variables and existing data sources, and application of the model.

3.0 STUDY AREA

The general study area is the Sub-Boreal Spruce biogeoclimatic zone (Pojar *et al.* 1984). It contains both the SBSd and SBSe subzones (Fig. 2). Pojar *et al.* (1984) give the following description of climate and vegetation. Climate of the SBS can be characterized as a cold sub-boreal continental humid type, with severe, snowy winters and relatively warm, moist, short summers, with light to intense rainfalls of short duration.

The SBSd (spruce subzone), ranges in elevation from 550 m to 1100 m and covers the lower elevations that contain the major settlements of the Bulkley Valley. The climate of the SBSd is intermediate between the SBSa (pine-spruce subzone) and the SBSe, with drier summers (mean precipitation 443 to 513 mm) and severe winters. Snowfall is considerably less and of shorter duration than the SBSe. Mean annual temperature is 2.1 to 4.0°C.

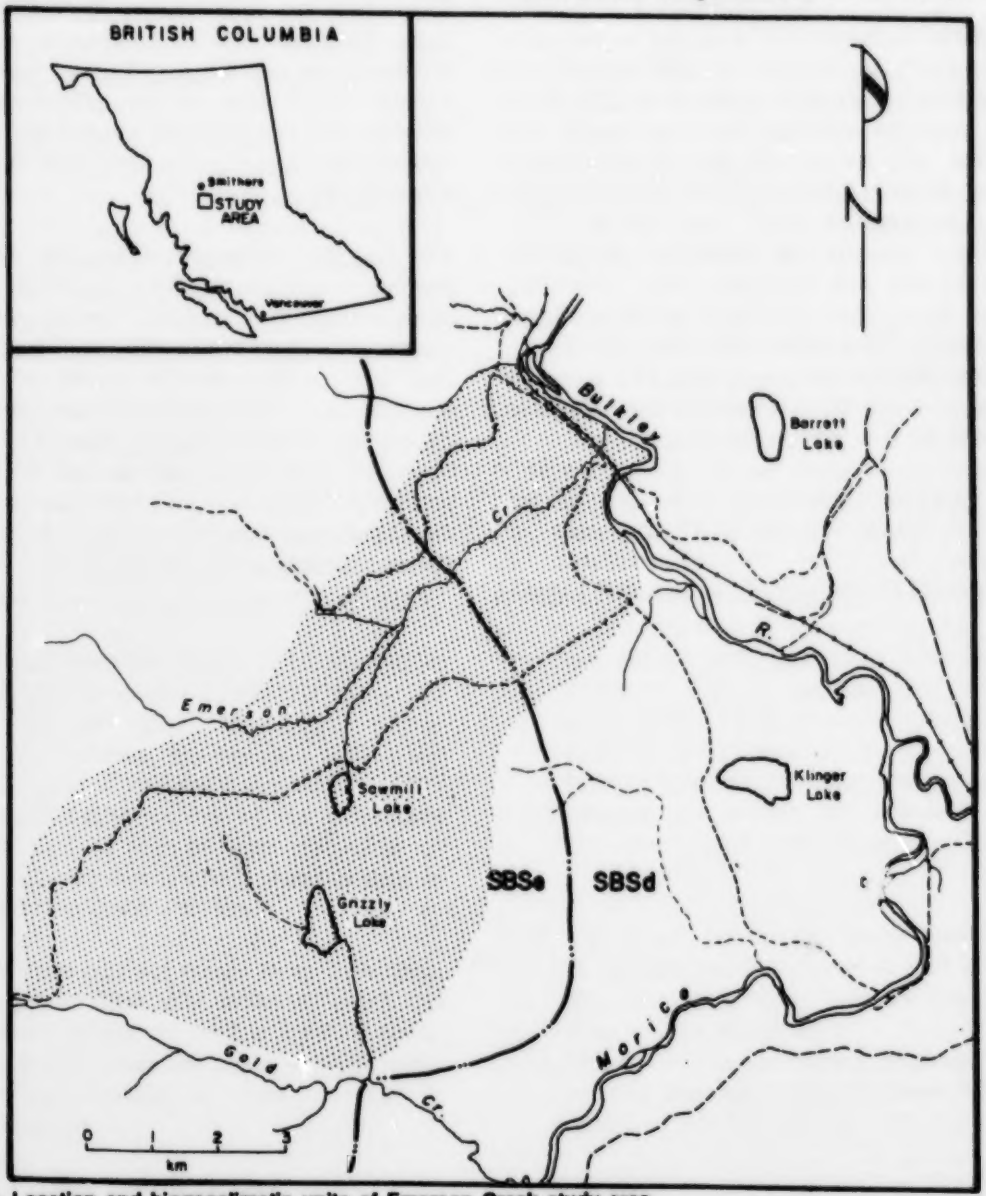

Figure 2. Location and biogeoclimatic units of Emerson Creek study area.

Dominant tree species are hybrid white spruce (*Picea glauca* x *engelmannii*), lodgepole pine (*Pinus contorta*), trembling aspen (*Populus tremuloides*) and black cottonwood (*Populus balsamifera*). Minor species include black spruce (*Picea mariana*), subalpine fir (*Abies lasiocarpa*) and paper birch (*Betula papyrifera*). The most abundant cover types are the pine-spruce or pine-spruce-aspen mixtures. Zonal ecosystems of the SBSd generally develop on morainal blankets, where organic horizons are 5 to 15 cm deep.

The SBSe (subalpine fir subzone) is the main timber producing area of the SBS zone (Pojar *et al.* 1984). Elevation ranges from 750 m to 1300 m. This subzone has the wettest and snowiest climate of all the SBS subzones within the Prince Rupert Forest Region. Mean annual temperature varies from 0.4 to 2.1°C. Dominant conifers are subalpine fir, hybrid white spruce, and lodgepole pine. Trembling aspen is a common seral species. Zonal ecosystems of the SBSe commonly develop on morainal blankets, however, they also occur on fluvial fans and fluvialglacial terraces. Organic horizons are 5 to 15 cm deep.

The intensive study area is located in the Emerson Creek watershed, 10 km west of Houston, B.C. and 50 km southeast of Smithers, B.C (Fig. 2). It is bounded by the height of land on the north side of Emerson Creek and on the north fork of Gold Creek, on the east by private cleared land and on the south by Gold Creek. Two small lakes (Grizzly and Sawmill) are located in the centre of the area. Elevation ranges from 700 m to 1200 m. The intensive study area contains both the SBSd and SBSe subzones (Fig. 2).

This area has been influenced by wildfire until recent times. Evidence suggests that stands in the SBS have been burned at least once every 300 years and most stands once every 100 years. There is evidence of fires as recent as 50 years ago (Ministry of Forests and Lands unpubl. data). Due to the effectiveness of modern fire suppression techniques, fire is unlikely to continue to be such a major influence (Pojar *et al.* 1984).

The area has a history of logging. Selective logging and onsite milling occurred over a large portion around 1965. During this time numerous winter roads and skid trails were built and currently provide access to parts of the study area. Recent logging has resulted in three large clearcuts ranging from 100 to 500 ha in size. The main road through the area, a popular and well used route, provides access to the Telkwa Mountains for recreational snowmobile and ATV enthusiasts.

4.0 METHODS

4.1 Hypothesis Testing

Hypotheses used in directing field research are discussed below. The general hypothesis that guides the project is that marten will move about their home ranges in response to the availability and distribution of habitat variables used for meeting life requisites. Underlying this are numerous specific hypotheses regarding the relationships between habitat variables and the provision of life requisites. Appendix A contains the figures that represent the relationships for hypotheses 1 - 8 and 10 - 13.

4.1.1 Habitat Selection.—

1. H_o: Abundance of marten prey items (small mammals) will not be greatest in habitats that have moisture regimes ranging from submesic to subhygric.
   H_a: Small mammal abundance will be greatest in moisture regimes ranging from sub-mesic to sub-hygric.

2. H_o: Abundance of small mammals will not be greatest in habitats that have percent cover of the low shrub strata between 30% and 100%.
   H_a: Small mammals will be most abundant in habitats that have percent cover of low shrubs ranging from 30% to 100%.

3. H_o: Small mammal abundance will not be greater in habitats with at least 100 m^3/ha of dead and down woody material than in habitats with <100 m^3/ha dead and down material.
   H_a: Small mammals will be more abundant in habitats with at least 100 m^3/ha of dead and down woody material than in those habitats with less.

4. H_o: Marten will not forage more in habitats with at least 100 m^3/ha of dead and down woody material at least 20 cm in diameter than in habitats with <100 m^3/ha material at least 20 cm in diameter.
   H_a: Marten will forage more in habitats that have at least 100 m^3/ha dead and down woody material at least 20 cm in diameter.

5. H_o: Marten will not forage more in habitats with at least 5 m^2/ha basal area of snags at least 20 cm dbh than in habitats with <5 m^2/ha basal area of snags at least 20 cm dbh.
   H_a: Marten will forage more in habitats with at least 5 m^2/ha basal area of snags that are at least 20 cm dbh.

6. H_o: Marten will not forage more in habitats that have at least 30% coniferous canopy cover that in those that have <30% coniferous canopy cover.
   H_a: Marten will forage more in habitats that have at least 30% coniferous canopy cover.

7. H_o: Marten will not locate resting dens more in habitats with at least 5 m^2/ha basal area of snags at least 40 cm dbh than in habitats with <5 m^2/ha basal area of snags at least 40 cm dbh.
   H_a: Marten will locate resting dens more in habitats with at least 5 m^2/ha basal area of snags at least 40 cm dbh.

8. H_o: Marten will not locate resting dens more in habitats with at least 100 m^3/ha dead and down woody material at least 20 cm diameter than in habitats with <100 m^3/ha dead and down woody material at least 20 cm in diameter.
   H_a: Marten will locate resting dens more in habitats with at least 100 m^3/ha of dead and down woody material at least 20 cm in diameter.

9. H_o: Marten will not locate resting dens more in habitats that have trees at least 40 cm dbh than in habitats than do not have trees at least 40 cm dbh.
   H_a: Marten will locate resting dens more in habitats that have trees at least 40 cm dbh.

10. H_o: Female marten will not locate maternal dens more in habitats with at least 5 m^2/ha basal area of snags at least 40 cm dbh than in habitats with <5 m^2/ha basal area of snags at least 40 cm dbh.
    H_a: Female marten will locate maternal dens more in habitats that have at least 5 m^2/ha basal area of snags >40 cm dbh.

11. H_o: Female marten will not locate maternal dens more in habitats with at least 100 m^3/ha of hard dead and down woody material at least 20 cm in diameter than in habitats with <100 m^3/ha of hard dead and down woody material at least 20 cm in diameter.
    H_a: Female marten will locate maternal dens more in habitats that have at least 100 m^3/ha of hard dead and down woody material at least 20 cm in diameter.

12. H_o: Marten will not use habitats that have at least 30% coniferous canopy cover more than habitats that have <30% coniferous canopy cover.
    H_a: Marten will use habitats that have at least 30% coniferous canopy cover more than habitats that have <30% coniferous canopy cover.

13. H_o: Marten frequency of use of habitats that do not provide all life requisites will not be positively correlated with those habitats' measures of habitat interspersion.
    H_a: Marten frequency of use of habitats that do not provide all life requisites will be positively correlated with those habitats' measures of habitat interspersion.

4.1.2 Model Verification.— The confirmation or rejection of the above hypotheses will form the basis for the development of the habitat variable/life requisite relationships that are the backbone of the HSI model. The model, as a unit, must also be tested. To accomplish this an easily obtained index of habitat value (= use) must be developed that corresponds to the habitat use patterns that radio-collared marten demonstrate. This index will then be used to test the model. The following hypotheses outline this test.

1. H_o: The frequency of radio-collared marten use of habitat types will be independent of the relative densities of marten tracks found within each habitat.
   H_a: Radio-collared marten habitat use frequency will be correlated with the relative densities of marten tracks found within those habitats. Rejection of H_o allows for the use of this track census index as a model testing tool.

2. H_o: Model ratings for habitats within the intensive study area will be independent of the track index for those habitats.
   H_a: Model ratings will correlate with track indices for habitats within the intensive study area.

3. H_o: Model ratings for both disturbed and undisturbed habitats outside of the intensive study area will be independent of the track indices for these habitats.
   H_a: Model ratings for both disturbed and undisturbed habitats will be correlated with the track indices for these habitats.

4.1.3 Population Density.— It is important to try and develop the link between the HSI index and some population parameter (Habitat Capability Model). The most feasible method of doing this with the proposed marten HSI model is to examine the relationship between the track index and population density.

1. H_o: Marten track densities will be linearly correlated with time since last snowfall.
   H_a: Marten track densities will not be linearly correlated with time since last snowfall.

2. H_o: Marten population densities (as determined by mark/recapture methods) will not be correlated with track indices.
   H_a: Marten population densities and track indices will be correlated.

4.2 Data Collection

Development of the HSI model requires completion of the following project tasks:

1. determine the population composition (age ratios, sex ratios, resident/transient ratios) within the study area;

2. quantify and map habitat within the study area;

3. determine habitat use of resident marten within the study area;

4. examine marten winter diet;

5. examine correlation between levels of radio-collared marten habitat use and track indices and if possible use these indices to test and verify the HSI model in other areas;

6. examine the relation between track density indices and model ratings for marten habitat in verification sites, including habitat within different harvesting and silvicultural regimes;

7. examine the link between track density and population density.

4.2.1 Capture.— Marten will be trapped in Tomahawk traps (24x25x66 cm) baited with meat scraps, fish and jam. Commercial marten lure may also be used. Straw bedding will be placed inside the traps and traps will be covered with plastic and conifer boughs to keep captured animals dry. Captured marten will be transferred to a handling cone (Archibald and Jessup 1984) and weighed. Marten will be immobilized with a 2:1 mixture of ketamine hydrochloride and xylazine hydrochloride (both 100 mg/ml) at a rate of 0.2 ml/100 g body weight.

Marten will be ear-tagged for future identification (Model 1005-1, National Band and Tag Co.) and adult resident marten will be fitted with radio collars (Model SMRC-5, Lotek Engineering Inc.). Resident marten are defined as those that have been in the study area for at least 3 months. Adults, in the absence of tooth aging information, will be identified by weight, size of sagittal crest, size of baculum and tooth wear. Sex will be determined by palpation for the bacula and examination for teats. A premolar tooth will be removed for aging by cementum analysis (Dix and Strickland 1986). Body measurements including length of body, limbs and feet, neck and chest girths will be taken.

Initial efforts at trapping on an experimental grid proved too labour intensive and will be modified to improve efficiency. Efforts will be directed at saturation trapping the study area using the network of existing roads for access. An attempt will be made to maintain 10 active transmitters on adult marten (preferably 6 females and 4 males) throughout two winter seasons (December-April).

4.2.2 Habitat Classification and Mapping.— Habitat will be classified and mapped by the Forest Sciences Section, Ministry of Forests in Smithers. Classification will follow the biogeoclimatic ecosystem classification system (BEC) (Pojar *et al.* 1987), and will include a seral component. Habitats will be mapped by pre-typing 1:10 000 colour air photos and ground truthing these polygons in the field. Full vegetation plots (Pojar *et al.* 1987) will be established at most ground truth sites. In addition, other information specific to model habitat variables will be collected, including stand mensuration plots to obtain stocking information for trees, snags and stumps. Volume of dead and down woody material will be measured using modifications of the methods used for assessing fuel loading for prescribed fire as described in Van Wagner (1968), Brown (1974), Brown and Roussopoulos (1974), McRae *et al.* (1979) and Trowbridge *et al.* (1987). (Habitat variables in each habitat type will be described with additional habitat plots.) The study area will be overlayed with a 200-m grid, which in turn will be blocked into groups of 25 grid intersection points, for reasons of access. Sampling blocks will be selected randomly.

4.2.3 Monitoring and Habitat Use.— Marten will be monitored daily when possible to obtain 1 location/marten/day. This frequency should avoid problems posed by non-independent relocations (Swihart and Slade 1985). A minimum of 40 locations/marten is necessary to describe home range properly. Marten will be monitored with Telonics model TR-2 receiver/scanners and 4-element Yagi antennas. Permanent telemetry stations will be established throughout the study area. Fixes will be recorded on a UTM-coordinate system and will be calculated using a computer triangulation program (Page, no date). Several 24-hour monitoring sessions are planned to determine if differences exist in habitat use and activity patterns between night and day. The sampling regime may have to be adjusted to account for these sessions.

Radio locations of marten will be overlayed on the habitat base map to determine the habitat used. In addition stationary marten will be located on the ground to identify denning sites. Resting and maternal den site characteristics will be described at the time of use and after snow melt. Data to be collected include habitat type, standard forest mensuration, volume of dead and down woody material and physical characters of the den.

Radio locations of mobile marten will be assigned to travel/foraging activity unless they are found to be part of a long distance, short-term migration. Variability in signal strength can be used to distinguish mobile and stationary marten.

4.2.4 Diet.— Marten winter diet and microtine prey availability will be examined using several methods. Scat collection within the study area will help determine prey use. A stratified systematic sampling scheme will be used to assess relative densities of small mammals in different habitat units. Small mammals will be live trapped during late summer and early fall using Sherman folding traps. Animals will be marked and released in a simple mark recapture study.

4.2.5 Interspersion of Habitat.— Measures of spatial arrangement of habitat may be obtained using a variety of techniques (Lyon *et al.* 1987). This process and the complex analysis of large quantities of data can now be computerized by geographic information systems (GIS). A computerized GIS system will be used to digitize the habitat map and obtain measures of interspersion for those habitat units lacking one or more life requisites. These measures of interspersions are mean distance measures to the nearest habitat providing the missing life requisite. In addition, interspersion will be examined using HSI means and variances in verification sites and by comparing track indices between these sites. Sites with equal mean HSI values but different variances should have different track indices. Those with higher variances should have lower track indices than those with lower variances.

4.2.6 Model Verification.— Verification is a critical step to ensure reliability of the model and its acceptance by resource managers in the geographic area of application. Several sites will be selected for verification, based on their similarity to habitat in the main study area, ease of access, and a lack of recent trapping history. The effect of recent trapping may be that areas of high suitability for marten receive little use due to a lack of individuals to occupy those areas. This will result in an unreliable test of the model. A track census index (Gyug 1988) will be developed in the Emerson Creek study area by recording track information along a number of transects. Use by marten as indicated by the track index will be compared to model predictions. Transects will be selected to cover an area of pre-determined size and as many different habitat types as possible. The sample effort necessary depends on track density. At the same time track census surveys will be carried out in verification sites. This verification process will be extended to additional sites in the third field season, to include sites that have had a variety of forest harvesting and silvicultural treatments.

4.2.7 Population Density.— We will try to tie the track index to population information obtained from live trapping and monitoring in the intensive study area. A mark recapture exercise will be used to develop a Lincoln index. The marked animals are those that have been fitted with radio collars. The whip antennae from the radio collars leave marks in the snow as the animals travel through the snow. The number of radio-collared animals in the sample area (transect grid), as determined by telemetry, is the known number of marked animals at the time of sampling. The recapture sample is the total number of tracks encountered on the track transects and the recaptures are those tracks with associated antennae marks. Track transects are laid out to cover a specified area. A density estimate can then be derived for this area.

5.0 PROJECT SCHEDULE

The following products and schedule are planned for the Marten HSI Research Project:

1. Project Working Plan - December 1988
2. Annual Progress Report/Working Plan
4. Job Completion Report - December 1991
5. HSI Model and User's Guide - December 1992
6. Lofroth's Thesis - December 1991
7. Scientific Journal Publications - Various Dates

A schedule of tasks required to complete the field research is outlined below in Table 4.

Table 4. Schedule of tasks for completion of Marten HSI Research Project.

Task	Schedule							
	1987	1988	1989	1990	1991	1992	1993	1994
Trapping	—	- —	- - -					
Monitoring	-	—	—					
Habitat Mapping			— -	-				
Habitat Variables			—	-	-			
Mapping Transects					-			
Verification Tracking			-	—	—			
Analyses/Writeup			-	-	-	-	—	
Model Computerization						—		
Handbook Development						—		
Training and Extension Development							—	
Training and Extension Delivery								—

6.0 PROJECT BUDGET

The budget presented below is that required to produce an effective, reliable product.

Year 1 1987/88

Salaries	$22,700
Equipment	6,800
TOTAL	29,500

Year 2 1988/89

Project Biologist	$22,900
Project Technicians	19,600
Vehicle Expenses	8,000
Equipment	6,500
Aircraft	2,000
Travel	2,000
TOTAL	61,000

Year 3 1989/90

Project Biologist	$24,700
Project Technician	21,600
Vehicle Expenses	8,000
Equipment	7,500
Aircraft	2,000
Travel	2,000
TOTAL	65,800

Year 4 1990/91

Project Biologist	$28,000
Project Technician	24,000
Vehicle Expenses	5,800
Equipment	3,500
Travel	2,500
TOTAL	63,800

Year 5 1991/92

Project Biologist	$31,000
Project Technician	25,000
Vehicle Expenses	6,000
Equipment	2,000
Travel	2,000
Handbook Layout	10,000
TOTAL	76,000

Year 6 1992/93

Project Biologist	$31,000
Project Technician	25,000
Model Computerization	7,000
Handbook Production	15,000
TOTAL	78,000

Year 7 1993/94

Project Biologist	$31,000
Training/Extension	32,000
TOTAL	63,000

PROJECT TOTAL	$437,100

The Habitat Conservation Fund is the main source of operational funds for the research phase of this project. It is proposed that Wildlife Habitat Canada be approached for funding to develop the user's manual and training program. Project biologist wages and FTE, vehicle, and equipment are supplied through the Research and Development Section of the Wildlife Branch. Monies for equipment expenses are provided by the Furbearer Management Section of the Wildlife Branch. Logistics and equipment are provided by the Skeena Region of Fish and Wildlife. Habitat mapping support and equipment are provided by the Ministry of Forests in Smithers.

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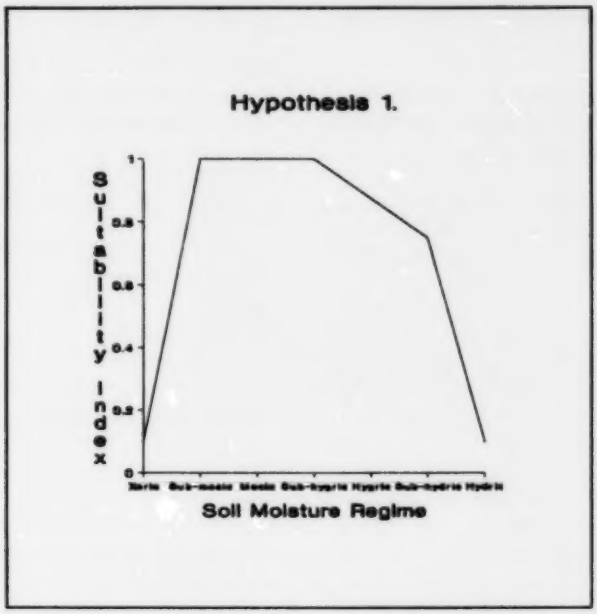
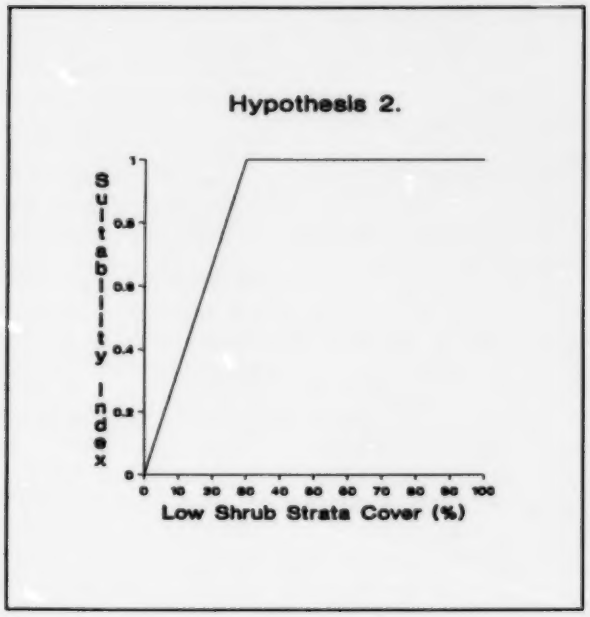
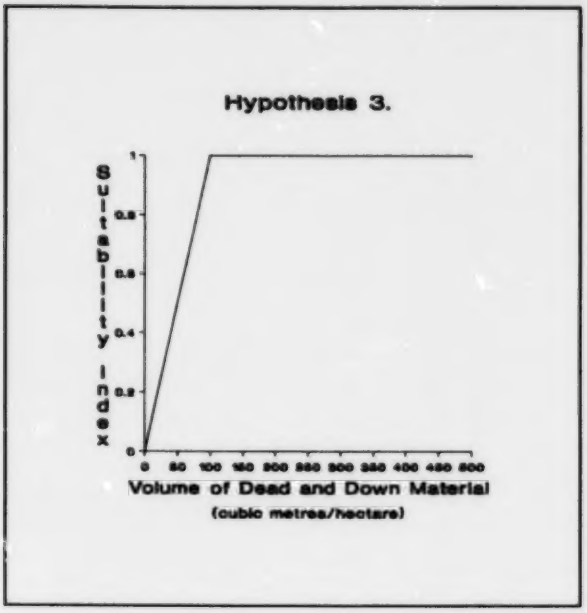
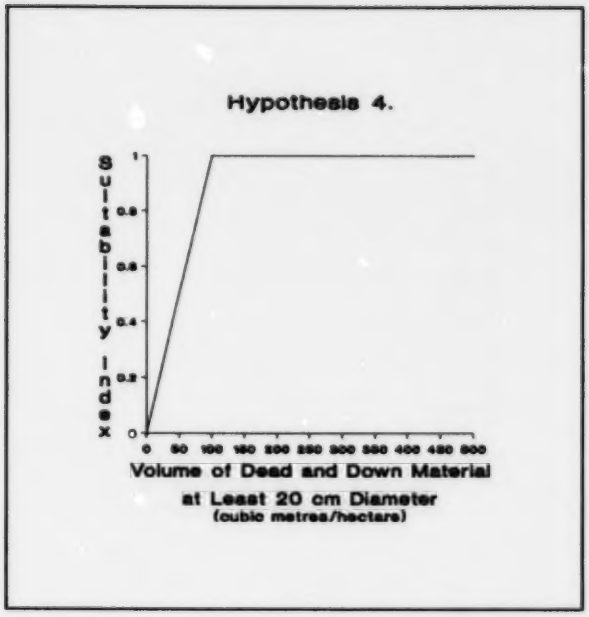
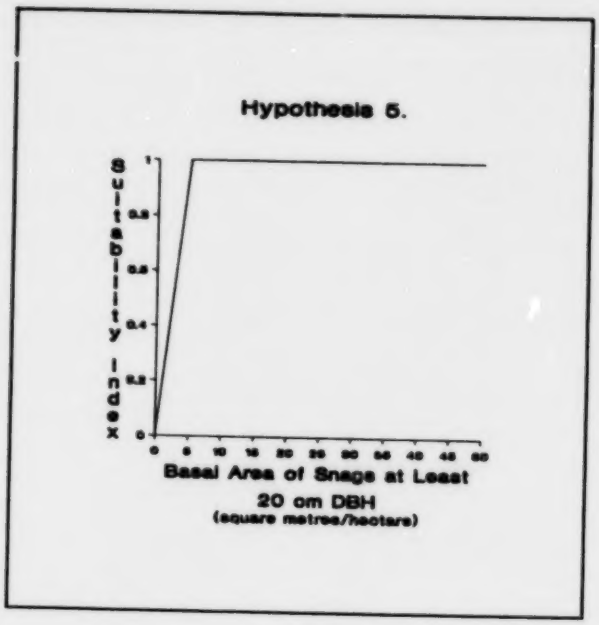
Appendix A. Hypothesized habitat variable/life requisite relationships.

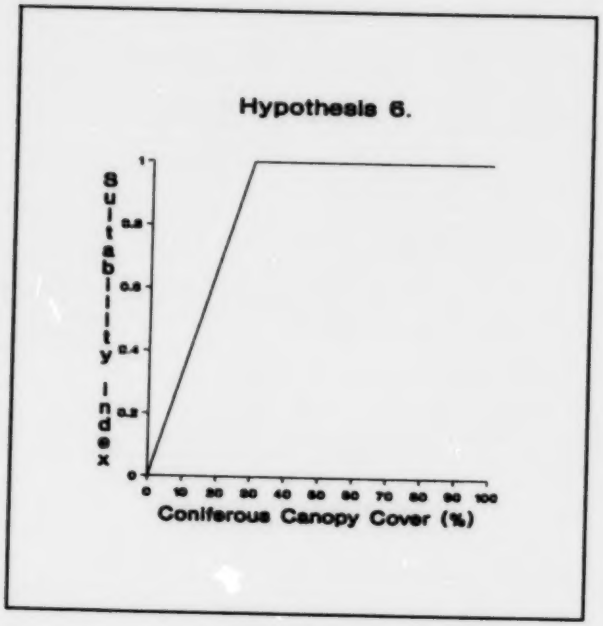


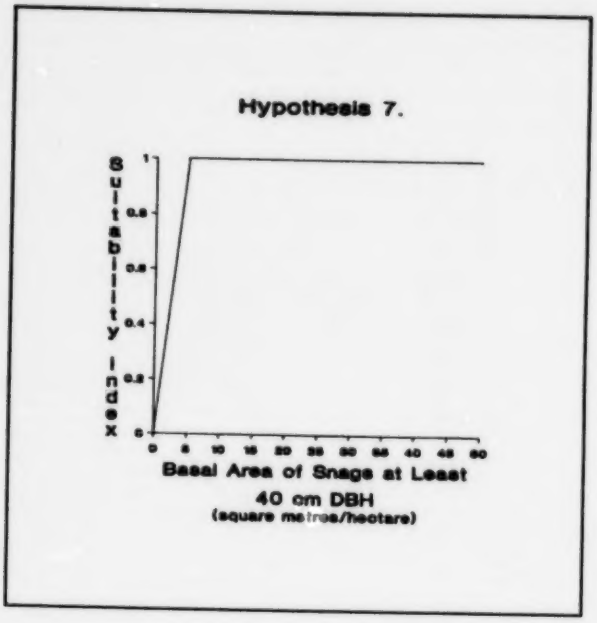


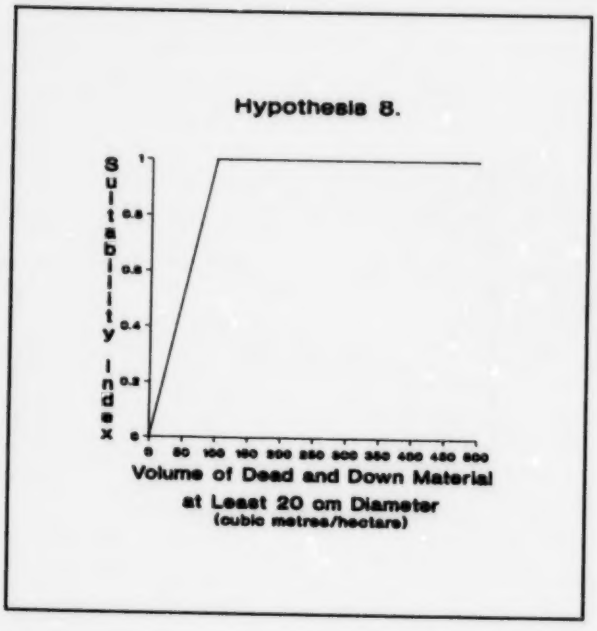

Hypothesis 3.
Suitability index
0
0.2
0.4
0.6
0.8
1
0 50 100 150 200 250 300 350 400 450 500
Volume of Dead and Down Material
(cubic metres/hectare)

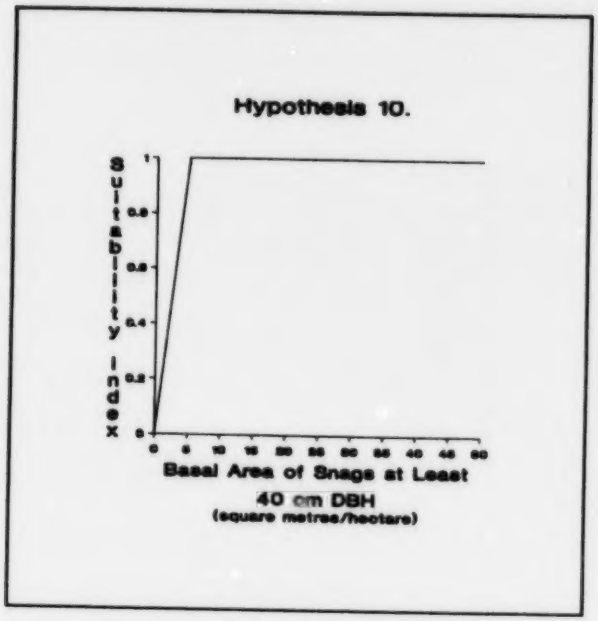

Hypothesis 4.
Suitability index
0
0.2
0.4
0.6
0.8
1
0 50 100 150 200 250 300 350 400 450 500
Volume of Dead and Down Material
at Least 20 cm Diameter
(cubic metres/hectare)

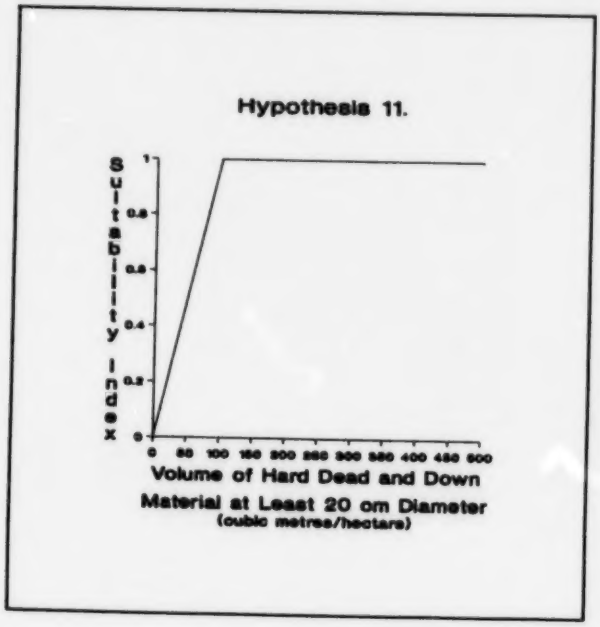

Hypothesis 5.
Suitability Index
Basal Area of Snags at Least
20 cm DBH
(square metres/hectare)

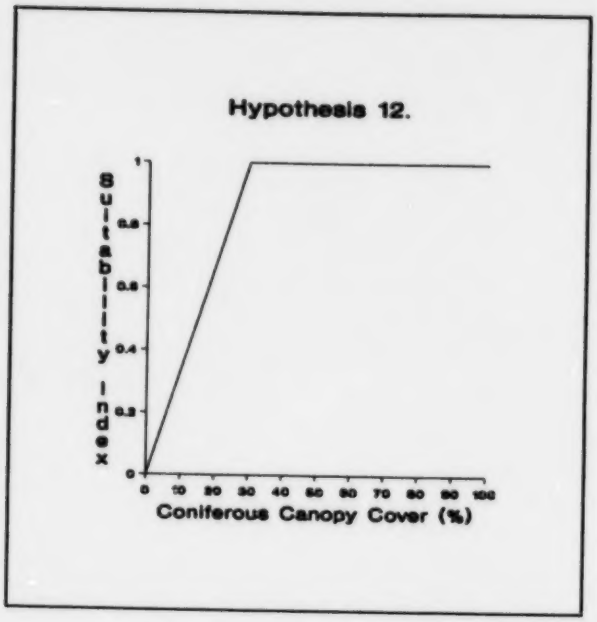

Hypothesis 6.
Suitability Index
Coniferous Canopy Cover (%)

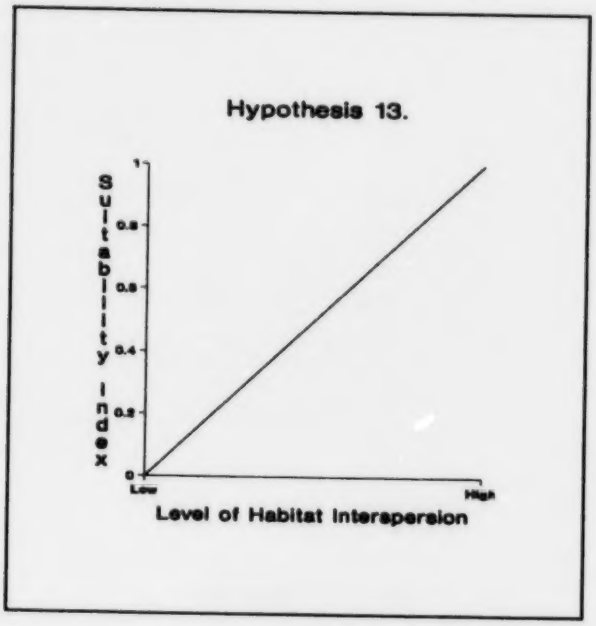

Hypothesis 7.
Suitability index
Basal Area of Snags at Least
40 cm DBH
(square metres/hectare)


Hypothesis 8.
Suitability index
Volume of Dead and Down Material
at Least 20 cm Diameter
(cubic metres/hectare)


Hypothesis 10.
Suitability index
Basal Area of Snags at Least
40 cm DBH
(square metres/hectare)


Hypothesis 11.
Suitability index
Volume of Hard Dead and Down
Material at Least 20 cm Diameter
(cubic metres/hectare)


Hypothesis 12.
Suitability Index
0
0.2
0.4
0.6
0.8
1
0 10 20 30 40 50 60 70 80 90 100
Coniferous Canopy Cover (%)


Hypothesis 13.
Suitability Index
0
0.2
0.4
0.6
0.8
1
Low
High
Level of Habitat Interspersion

Wildlife Working Reports should not be cited because of the preliminary nature of the data they contain

WR-1 Progress report - coastal grizzly research project: Year 1. A.N. Hamilton. First printed October 1984, revised October 1986. 32pp. (Also printed as WHR-9).

WR-2 Progress report - year 2 - 1983, working plan - year 3 - 1984. Coastal grizzly research project. A.N. Hamilton and W.R. Archibald. First printed October 1984, revised October 1986. 32pp. (Also printed as WHR-10).

WR-3 Telemetry: comments and suggestions from the coastal grizzly project 1983. A.E. Derocher. October 1984. (Also printed as WHR-11).

WR-4 Habitat types of the Kimsquit River estuary. C. Clement. October 1984. 27pp. (Also printed as WHR-12).

WR-5 Biogeoclimatic units and ecosystem associations of the Kimsquit drainage. C. Clement. October 1984. 93pp. (Also printed as WHR-13).

WR-6 Kechika Enhancement Project of northeastern B.C.: wolf/ungulate management. 1983-84 annual report. J.P. Elliott. October 1984. 25pp.

WR-7 Muskwa Project working plan. J.P. Elliott. December 1984. 32pp.

WR-8 Muskwa Wolf Management Project of northeastern B.C. 1983-84 annual report. J.P. Elliott. December 1984. 23pp.

WR-9 Kechika Enhancement Project of northeastern B.C.. Revised working plan for 1984-87. J.P. Elliott. December 1984. 12pp.

WR-10 Home on the range: how to cook an urban goose. W.T. Munro, R.T. Sterling, and M.D. Noble. February 1985. 19pp.

WR-11 Effect of wolf control on black-tailed deer in the Nimpkish Valley on Vancouver Island. Progress report -1983 August 31 to 1984 August 31. K. Atkinson and D. Janz. March 1985. 22pp.

WR-12 1983 southeastern Skeena regional moose abundance and composition survey. B. van Drimmelen. June 1985. 47pp.

WR-13 Kechika Enhancement Project of northeastern B.C.: wolf/ungulate management. 1984-85 annual report. J.P. Elliott. September 1985. 28pp.

WR-14 Muskwa Wolf Management Project of northeastern B.C. 1984-85 annual report. J.P. Elliott. September 1985. 44pp.

WR-15 Caribou habitat use on the Level Mountain and Horseranch ranges, British Columbia. M.A. Fenger, D.S. Eastman, C.J. Clement, and R.E. Page. 1986. 41pp + 4 maps. (Also printed as Surveys and Resource Mapping Branch Working Report WR-8).

WR-16 Working plan - coastal grizzly research project. W.R. Archibald and A.N. Hamilton. October 1985. 27pp. (Also printed as WHR-21).

WR-17 Progress report - year 3 - 1984, working plan - year 4 - 1985. Coastal grizzly research project. W.R. Archibald, A.N. Hamilton, and E. Lofroth. October 1985. 65pp. (Also printed as WHR-22).

WR-18 Morice biophysical study, 93L/SW. B. Fuhr, M. Fenger, L. Lacelle, R. Marsh, and M. Rafiq. March 1986. 63pp + 9 maps.

WR-19 Effect of wolf control on black-tailed deer in the Nimpkish Valley on Vancouver Island. Progress report - 1984 August 31 to 1985 August 31. K. Atkinson and D.W. Janz. March 1986. 27pp.

WR-20 Kechika Enhancement Project of northeastern B.C.: wolf/ungulate management. 1985-86 annual report. J.P. Elliott. December 1986. 17pp.

WR-21 Muskwa Wolf Management Project of northeastern B.C. 1985-86 annual report. J.P. Elliott. December 1986. 15pp.

WR-22 Progress report - year 4 - 1985, working plan - year 5 - 1986. Coastal grizzly research project. A.N. Hamilton, W.R. Archibald, and E. Lofroth. February 1987. 90pp. (Also printed as WHR-26).

WR-23 Critical habitat of caribou (*Rangifer tarandus caribou*) in the mountains of southern British Columbia. K. Simpson, K. Hebert, and G.P. Woods. February 1987. 13pp.

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Continued from inside back cover

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WR-45 Biophysical habitat units of the Mosley Creek study area: expanded legend and interpretations. E.C. Lea and R.C. Kowall. March 1990.

WR-46 Habitat Management Section. Annual General Meeting. Yellowpoint Lodge - 1989 April 25-27. Wildlife and Recreational Fisheries Branches, Ministry of Environment. July 1990. 107pp.

WR-47 Working plan — Khutzeymateen Valley grizzly bear study. A.N. Hamilton and J.A. Nagy. September 1990. 35pp. (Also printed as WHR-28).

WR-48 Khutzeymateen Valley grizzly bear study. Annual progress report - year 1 (1989/90), annual working plan - year 2 (1990/91). J.A. Nagy and A.G. MacHutchon. January 1991. 44pp. (Also printed as WHR-29).

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WR-50 Marten habitat suitability research project - working plan. E.C. Lofroth and V. Banci. January 1991. 31pp.

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